Announcements

- Homework for tomorrow…

  Ch. 22, CQ 7, Probs. 16, 18, & 20

  CQ3: a) decreases b) increases c) decreases d) 1.0 x 10^{-6} m

  22.2: 450 nm

  22.4: 1.2 mm

  22.8: 500 nm

- Office hours…

  MW 10-11 am

  TR 9-10 am

  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm

  F 8-11 am, 2-5 pm

  Su 1-5 pm

Chapter 22

Wave Optics

(The Diffraction Grating & Single-Slit Diffraction)

Last time…

- The *intensity* of the *double-slit* interference pattern at position *y*…

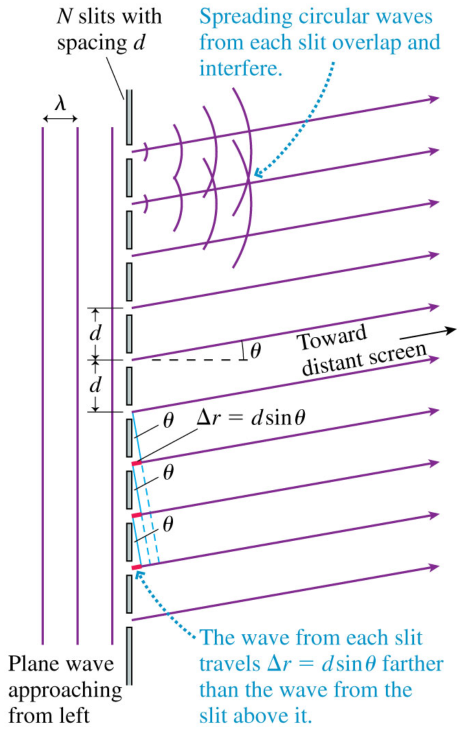
$$\boxed{I_{double} = 4I_1 \cos^2\left(\frac{\pi d}{\lambda L} y\right)}$$

- The *angular positions* of the *bright fringes* for the *diffraction grating*…

$$\boxed{d \sin\theta_m = m\lambda} \quad , \quad m = 0, 1, 2, \ldots$$

- The m^th *bright fringe* for the *diffraction grating*

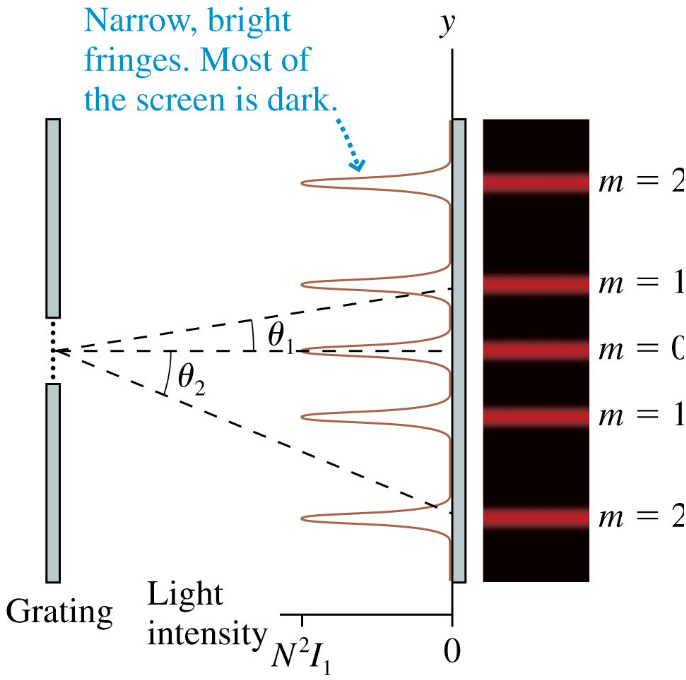
$$\boxed{y_m = L \tan\theta_m} \quad , \quad m = 0, 1, 2, \ldots$$



22.3
The Diffraction Grating

Notice:

- a is the *amplitude* of the wave through 1 slit.
- The *wave amplitude* at the points of *constructive interference* is Na.
- What are the *intensities* of the bright fringes?

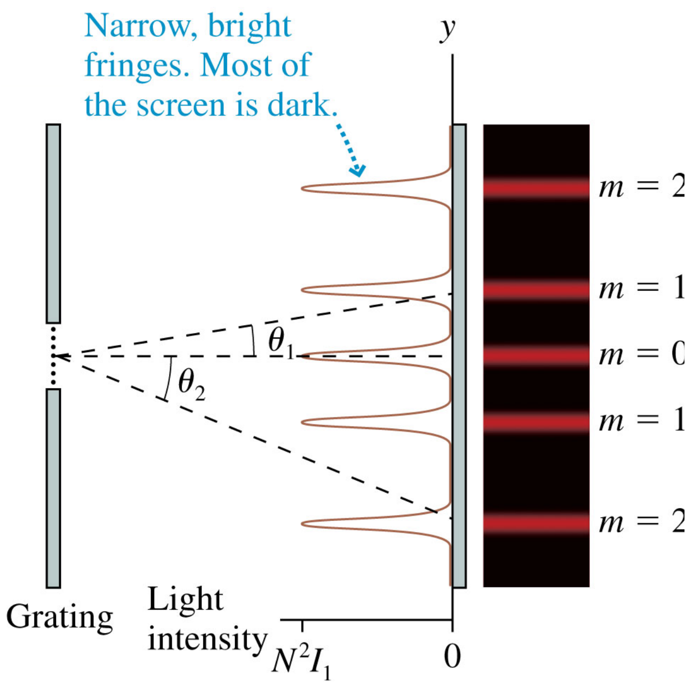


22.3
The Diffraction Grating

Notice:

- *a* is the *amplitude* of the wave through 1 slit.
- The *wave amplitude* at the points of *constructive interference* is *Na*.
- What are the *intensities* of the bright fringes?

$$\boxed{I_{max} = N^2 I_1}$$



Notice:

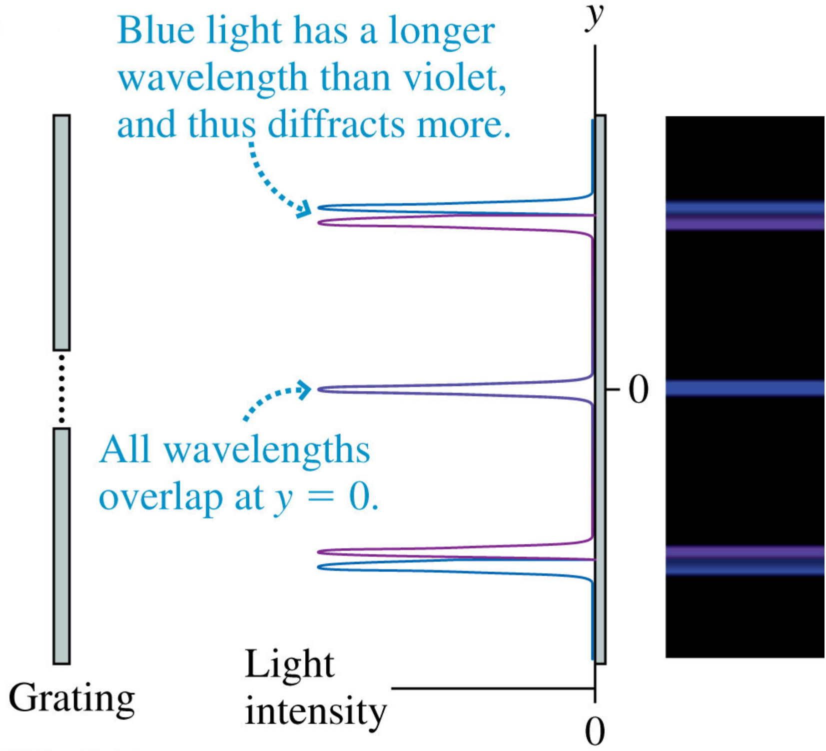
As *N increases*, the fringes get *narrower*.

Why *must* this be the case?

22.3
The Diffraction Grating

- Diffraction gratings can be used to *measure* the wavelengths of light.

- If the incident light consists of two *slightly different wavelengths*, each wavelength will be diffracted at a *slightly different angle*.



Quiz Question 1

In a laboratory experiment, a diffraction grating produces an interference pattern on a screen. If the *number* of slits in the grating is *increased*, with everything else (including the slit spacing) the *same*, then

1. The fringes stay the same brightness and get closer together.
2. The fringes stay the same brightness and get farther apart.
3. The fringes stay in the same positions but get dimmer and wider.
4. The fringes stay in the same positions but get brighter and narrower.
5. The fringes get brighter, narrower, and closer together.

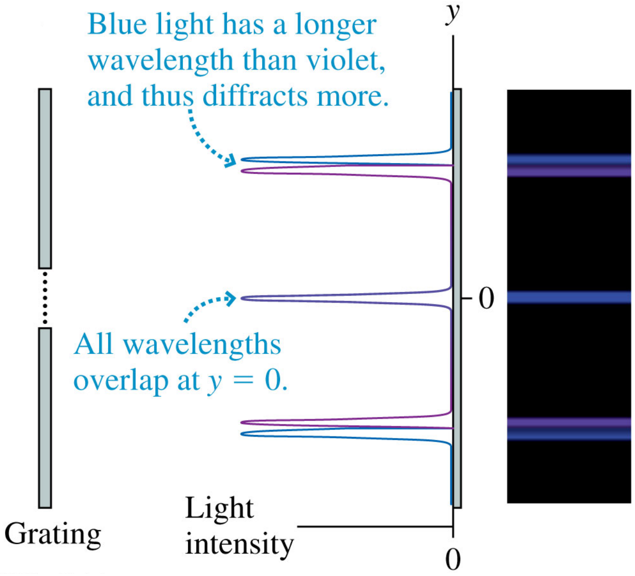
i.e. 22.3: Measuring wavelengths emitted by sodium atoms

Light from a sodium lamp passes through a diffraction grating having 1000 slits per millimeter. The interference pattern is viewed on a screen 1.000 m behind the grating. Two bright yellow fringes are visible 72.88 cm and 73.00 cm from the central maximum.

What are the wavelengths of these two fringes?

$d \sin\theta_m = m\lambda \quad m = 0, 1, 2$

$y_m = L \tan\theta_m \quad m = 0, 1, 2$



$L = 1.000\,m$

$m = 1$

$y_1 = 0.7288\,m$

$y_2 = 0.7300\,m$

$d = 1.000 \times 10^{-6}\,m$

$y_1 = L \tan\theta_1$

$\tan^{-1}\left(\frac{y_1}{L}\right) = \theta_1 \qquad \tan^{-1}\left(\frac{y_2}{L}\right) = \theta_2$

$\theta_1 = 36.08^\circ \qquad \theta_2 = 36.13^\circ$

$\lambda_1 = \frac{d \sin\theta_1}{1} \qquad \lambda_2 = \frac{d \sin\theta_2}{1}$

$\lambda_1 = 589.8\,nm \qquad \lambda_2 = 589.6\,nm$

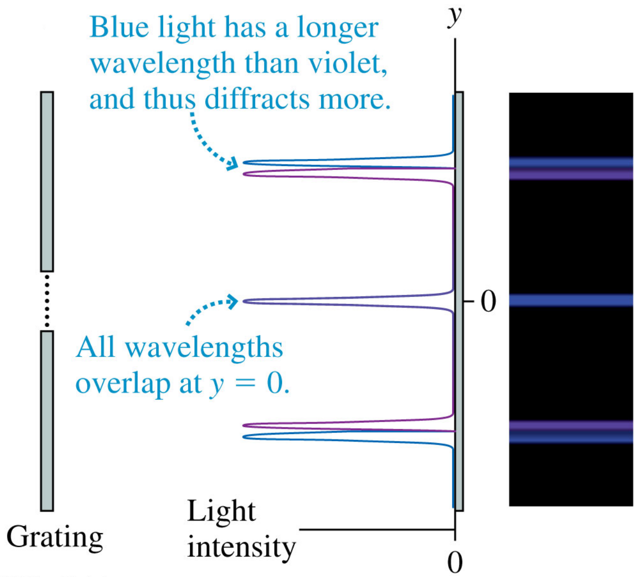
i.e. 22.3: Measuring wavelengths emitted by sodium atoms

Light from a sodium lamp passes through a diffraction grating having 1000 slits per millimeter. The interference pattern is viewed on a screen 1.000 m behind the grating. Two bright yellow fringes are visible 72.88 cm and 73.00 cm from the central maximum.

What are the wavelengths of these two fringes?

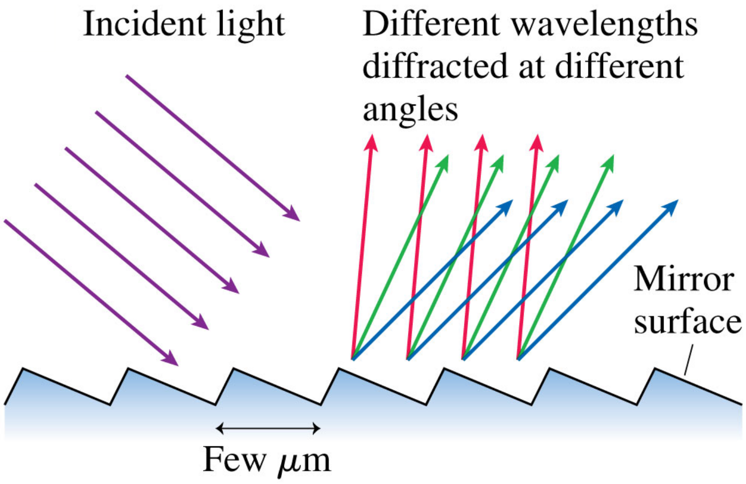
Notice: This is *spectral analysis!*

Because NO other element emits these 2 wavelengths, the doublet can be used to identify the presence of sodium in a sample of unknown composition.



Reflection Gratings…

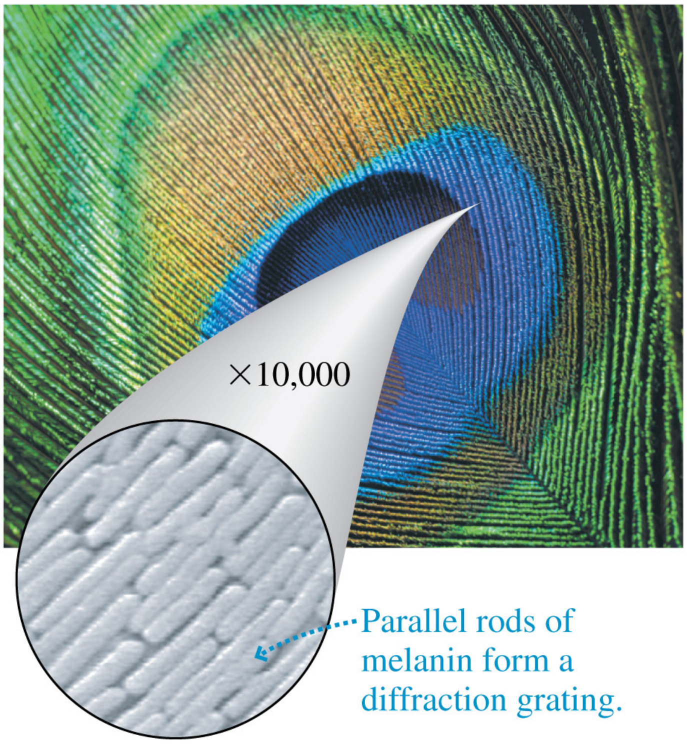
- Some diffraction gratings are manufactured as *reflection gratings*.
- The interference pattern is *exactly* the same as the interference pattern of light transmitted through N parallel slits.



A reflection grating can be made by cutting parallel grooves in a mirror surface. These can be very precise, for scientific use, or mass produced in plastic.

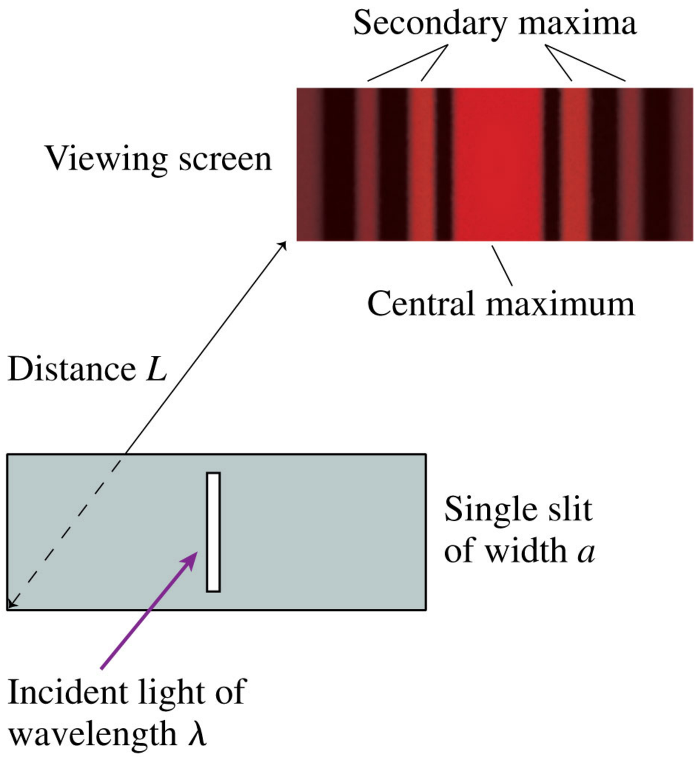
Reflection Gratings…

- Naturally occurring reflection gratings are responsible for some forms of color in nature.
- A peacock feather consists of nearly parallel rods of melanin, which act as a reflection grating!



22.4:
Single-Slit Diffraction

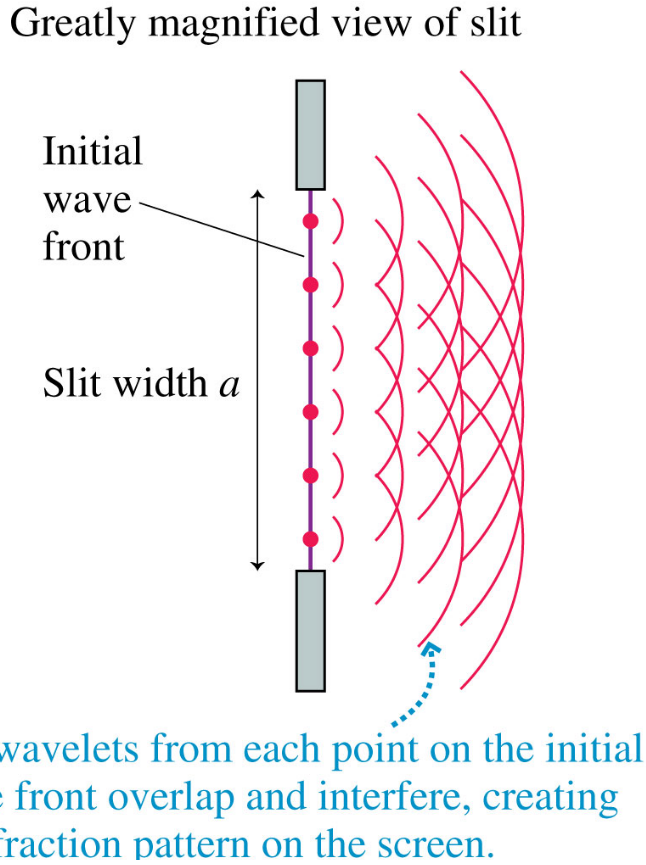
- Diffraction through a tall, narrow slit is known as *single-slit diffraction*.
- A viewing screen is placed distance L behind the slit of width a, and we will assume that $L >> a$.



Huygens' Principle (two steps)

1. Each point on a wave front is the *source* of a spherical wavelet that spreads out at the wave speed.

2. At a later time, the shape of the wave front is the line *tangent* to all the wavelets

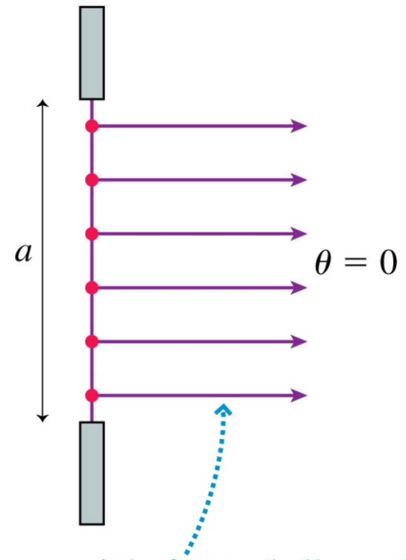


Single-Slit Diffraction…

- The figure shows the paths of several wavelets that travel straight ahead to the central point on the screen.

- The screen is *very* far to the right in this magnified view of the slit.

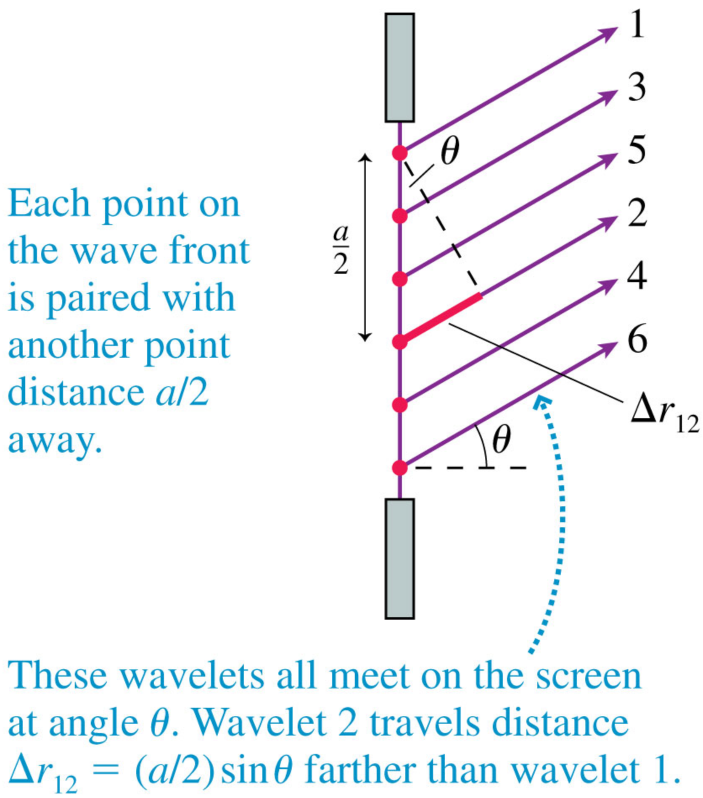
- The paths are *very* nearly parallel to each other, thus all the wavelets travel the same distance and arrive at the screen *in phase* with each other, therefore *constructive interference* occurs.



The wavelets going straight forward all travel the same distance to the screen. Thus they arrive in phase and interfere constructively to produce the central maximum.

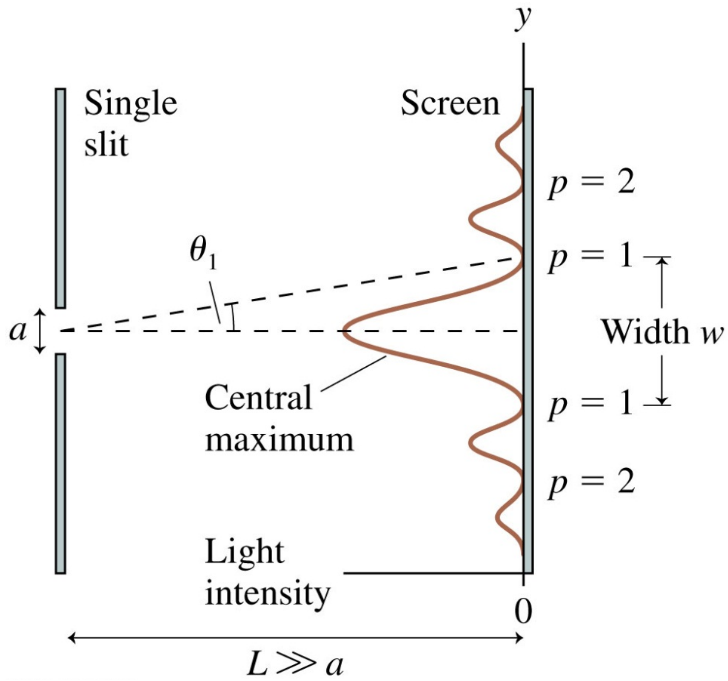
Single-Slit Diffraction…

- Wavelets 1 and 2 start from points that are $a/2$ apart.
- Each point on the wave front can be paired with another point a distance $a/2$ away.
- If the path-length difference is $\Delta r = \lambda/2$, the wavelets arrive at the screen out of phase and interfere destructively.



Single-Slit Diffraction…

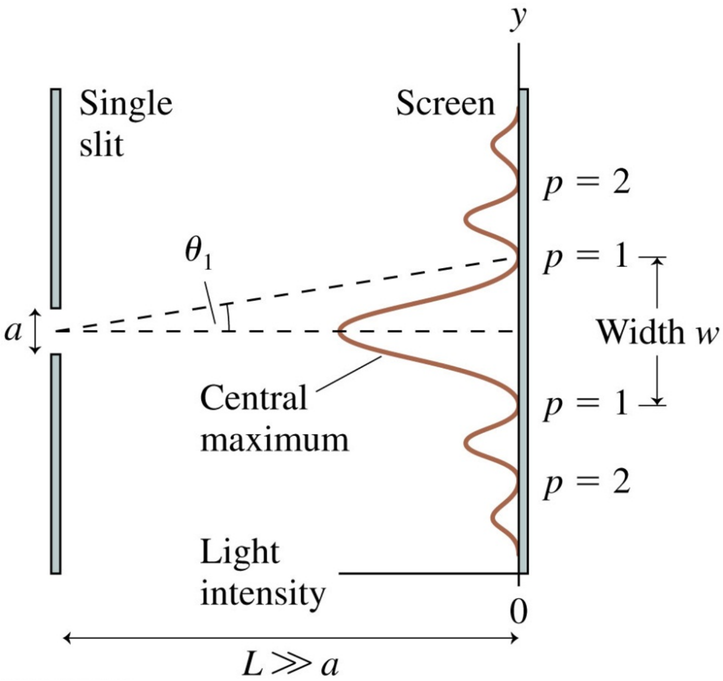
- The light pattern from a single slit consists of a *central maximum* flanked by a series of weaker *secondary maxima* and dark fringes.
- The *dark fringes* occur at angles:



Single-Slit Diffraction…

- The light pattern from a single slit consists of a *central maximum* flanked by a series of weaker *secondary maxima* and dark fringes.
- The *dark fringes* occur at angles:

$$\boxed{\theta_p = p\frac{\lambda}{a}} \quad , \qquad p = 1, 2, 3, \ldots$$



Notice:

- θ_p is in *radians*.
- $p = 0$ is *excluded!*
- above expression is the *same* as the m^{th} *maximum* of the *double-slit interference pattern*!